CLAIMS

1. An optical fibre having a longitudinal, optical axis, and a cross section perpendicular to the longitudinal axis, the optical fibre being adapted to guide light at an operating wavelength λ, the optical fibre comprising:
   a. a first core region disposed around the longitudinal, optical axis, the first core region exhibiting a predetermined refractive index profile n_{core-1};
   b. a second core region surrounding the first core region, the second core region exhibiting a predetermined refractive index profile n_{core-2};
   c. a cladding region surrounding the second core region and comprising a multitude of longitudinally extending spaced apart micro-structural holes disposed in a cladding material, the cladding material having a refractive index n_{clad}, the holes having cross sectional dimensions $d_i(z)$ and mutual centre to centre distances $\Lambda_{ij}(z)$, z being a coordinate along the longitudinal axis of the optical fibre;
   d. a first fibre cross section having a relatively larger area;
   e. a second fibre cross section having a relatively smaller area;
   f. the first and second fibre cross sections being separated by a tapered length of the optical fibre over which the cross-sectional physical dimensions of the fibre – including the micro-structural holes - are tapered down from the first to the second cross section; and

   wherein the first and second cross sectional areas, the refractive index profiles n_{core-1}, n_{core-2} of the first and second core regions, the refractive index n_{clad} of the cladding region and the cross sectional dimensions d_i and mutual centre to centre distances Λ_{ij} of the micro-structural holes in the first and second cross sectional areas are adapted – at the operating wavelength – to provide a mode field of a guided mode of the optical fibre with a diameter MFD_1 in the first cross section, and a mode field with a diameter MFD_2 in the second cross section, and wherein MFD_2 is larger than or equal to MFD_1.

2. An optical fibre according to claim 1 wherein the micro-structural holes are arranged in a substantially periodic pattern when viewed in a cross section of the optical fibre perpendicular to the longitudinal axis, the periodicity being defined by the location of the centres of the micro-structural elements.

3. An optical fibre according to claim 1 or 2 wherein in the second fibre cross section, the cross sectional dimensions of at least innermost holes of the cladding region are larger than zero.

4. An optical fibre according to claim 3 wherein at least the innermost holes have substantially similar ratio of cross sectional dimension to mutual centre to centre distance d/Λ at the first and second cross sections.

5. An optical fibre having a longitudinal, optical axis, and a cross section perpendicular to the longitudinal axis, the optical fibre being adapted to guide light at an operating wavelength λ, the optical fibre comprising:
    a. a first core region disposed around the longitudinal, optical axis, the first core region exhibiting a predetermined refractive index profile n_{core-1};
    b. a second core region surrounding the first core region, the second core region exhibiting a predetermined refractive index profile n_{core-2};.
    c. cladding region surrounding the second core region, the cladding region having a refractive index n_{clad};
    d. a first fibre cross section having a relatively larger area;
    e. a second fibre cross section having a relatively smaller area;
    f. the first and second fibre cross sections being separated by a tapered length of the optical fibre over which the cross-sectional physical dimensions of the are tapered down from the first to the second cross section; and

wherein the first and second cross sectional areas, the refractive index profiles of the first and second core regions and the refractive

index n_{clad} of the cladding region are adapted – at the operating wavelength – to provide a mode field of a guided mode of the optical fibre with a diameter MFD_1 in the first cross section, and a mode field with a diameter MFD_2 in the second cross section, and wherein MFD_2 is larger than or equal to MFD_1.

6. An optical fibre according to any of the preceding claims further comprising an intermediate region surrounding the first core region and being surrounded by the second core region.

7. An optical fibre according to claim 6 wherein the intermediate region is disposed adjacent to the first and second core regions.

8. An optical fibre according to claim 6 or 7 wherein the intermediate region exhibits a predetermined refractive index profile n_{ir} and wherein $n_{ir} < n_{core-1}$ and $n_{ir} < n_{core-2}$.

9. An optical fibre according to any one of claims 6-8 wherein the geometrically averaged refractive index $n_{g,core-1,ir}$ of the first core and intermediate regions is substantially equal to the refractive index n_{core-2} of the second core region.

10. An optical fibre according to claim 9 wherein the absolute value of the difference between $n_{g,core-1,ir}$ and n_{core-2} is smaller than $5 \cdot 10^{-3}$, such as smaller than $1 \cdot 10^{-3}$, such as smaller than $0.8 \cdot 10^{-3}$, such as smaller than $0.5 \cdot 10^{-3}$, such as smaller than $0.3 \cdot 10^{-3}$, such as smaller than $0.1 \cdot 10^{-3}$.

11. An optical fibre according to any one of claims 1-10 wherein the refractive index profile of the first core region is a step-index-profile with an index-step Δn_1 down to the refractive index n_{core-2} of the second core region.

12. An optical fibre according to claim 11 wherein Δn_1 is larger than $1 \cdot 10^{-3}$, such as larger than $5 \cdot 10^{-3}$, such as larger than $6 \cdot 10^{-3}$, such as larger than $10 \cdot 10^{-3}$.

13. An optical fibre according to any one of claims 1-12 wherein the refractive index profile of the first core region is a step-index-profile with an index-step $\Delta n_{1\text{-clad}}$ down to the refractive index of the cladding material n_{clad}.

14. An optical fibre according to claim 13 wherein $\Delta n_{1\text{-clad}}$ is larger than $1 \cdot 10^{-3}$, such as larger than $5 \cdot 10^{-3}$, such as larger than $6 \cdot 10^{-3}$, such as larger than $10 \cdot 10^{-3}$.

15. An optical fibre according to claim 13 when referring to any one of claims 1-4 or 6-12 wherein Δn_1 is identical to $\Delta n_{1\text{-clad}}$.

16. An optical fibre according to any one of claims 6-15 wherein the refractive index profile of the intermediate region is a step-index-profile with an index-step Δn_2 up to the refractive index $n_{core\text{-}2}$ of the second core region.

17. An optical fibre according to claim 16 wherein Δn_2 is larger than $0.1 \cdot 10^{-3}$, such as larger than $0.5 \cdot 10^{-3}$, such as larger than $1 \cdot 10^{-3}$, such as larger than $5 \cdot 10^{-3}$, such as larger than $10 \cdot 10^{-3}$.

18. An optical fibre according to any one of claims 6-17 wherein the refractive index profile of the intermediate region is a step-index-profile with an index-step $\Delta n_{2\text{-clad}}$ up to the refractive index of the cladding material n_{clad}.

19. An optical fibre according to claim 18 wherein $\Delta n_{2\text{-clad}}$ is larger than $0.1 \cdot 10^{-3}$, such as larger than $0.5 \cdot 10^{-3}$, such as larger than $1 \cdot 10^{-3}$, such as larger than $5 \cdot 10^{-3}$, such as larger than $10 \cdot 10^{-3}$.

20. An optical fibre according to any one of claims 6-19 wherein the refractive index profile of the second core region is a step-index-profile with an index-step Δn_3 down to the refractive index of the surrounding cladding region.

21. An optical fibre according to claim 20 wherein Δn_3 is smaller than $5\cdot10^{-3}$, such as smaller than $3\cdot10^{-3}$, such as smaller than $1\cdot10^{-3}$, such as smaller than $0.8\cdot10^{-3}$, such as smaller than $0.5\cdot10^{-3}$, such as smaller than $0.3\cdot10^{-3}$.

22. An optical fibre according to claim 15 wherein Δn_1 is in the range from $1\cdot10^{-3}$ to $2\cdot10^{-2}$, and Δn_2 is in the range from $0.1\cdot10^{-3}$ to $2\cdot10^{-2}$, and Δn_3 is in the range from $0.1\cdot10^{-3}$ to $1\cdot10^{-2}$.

23. An optical fibre according to any one of claims 1-22 wherein said first core region has a NA_{core-1} and dimension, $d_{2,core-1}$ in said second fibre cross section, and wherein $2\pi/\lambda*d_{2,core-1}/2*NA_{core-1}$ is less than 2.

24. An optical fibre according to any one of claims 1-23 wherein said first core region has a NA_{core-1} and dimension, $d_{1,core-1}$ in said first fibre cross section, and wherein $2\pi/\lambda*d_{1,core-1}/2*NA_{core-1}$ is less than 4.

25. An optical fibre according to any one of claims 1-24 wherein
   a. the first core region has a numerical aperture NA_{core-1} and a cross-sectional dimension $d_{1,core-1}$ in said first fibre cross section, and a cross-sectional dimension $d_{2,core-1}$ in said second fibre cross section;
   b. the second core region has a refractive index n_{core-2}, a numerical aperture NA_{core-2} in said second fibre cross section, a cross-sectional dimension $d_{1,core-2}$ in said first cross section, and a cross-sectional dimension $d_{2,core-2}$ in said second fibre cross section;
   c. an outer cladding region surrounding said second core region, said outer cladding region having a refractive index $n_{1,clad}$ or effective refractive index $n_{1,eff,clad}$ in said first fibre cross section and $n_{2,clad}$ or $n_{2,eff,clad}$ in said second fibre cross section;
   d. $n_{core-1} > n_{core-2}$;
   e. $n_{1,clad} < n_{core-2} < 1.002*n_{1,clad}$; or $n_{1,eff,clad} < n_{core-2} < 1.002*n_{1,eff,clad}$;
   f. $d_{1,core-1} > 1.3*d_{2,core-1}$
   g. $d_{2,core-2}$ is larger than or equal to $d_{1,core-1}$;
   h. $2\pi/\lambda*d_{1,core-1}/2*NA_{core-1}$ is less than 4;
   i. $2\pi/\lambda*d_{2,core-1}/2*NA_{core-1}$ is less than 2;
   j. $2\pi/\lambda*d_{2,core-2}/2*NA_{core-2}$ is less than 4.

26. An optical fibre according to claim 25, wherein $MFD_2 \geq 1.1*MFD_1$, such as $MFD_2 \geq 1.2*MFD_1$, such as $MFD_2 \geq 1.3*MFD_1$, such as $MFD_2 \geq 1.4*MFD_1$, such as $MFD_2 \geq 1.5*MFD_1$, such as $MFD_2 \geq 1.8*MFD_1$, such as $MFD_2 \geq 2.0*MFD_1$, such as $MFD_2 \geq 2.5*MFD_1$, such as $MFD_2 \geq 3.0*MFD_1$.

27. An optical fibre according to claim 25 or 26, wherein $d_{1,core-1} > 1.5*d_{2,core-1}$, such as $d_{1,core-1} > 1.8*d_{2,core-1}$, such as $d_{1,core-1} > 2.0*d_{2,core-1}$, such as $d_{1,core-1} > 2.5*d_{2,core-1}$, such as $d_{1,core-1} > 3.0*d_{2,core-1}$, such as $d_{1,core-1} > 3.5*d_{2,core-1}$, such as $d_{1,core-1} > 4.0*d_{2,core-1}$.

28. An optical fibre according to any one of the claims 25-27, wherein $d_{2,core-2} \geq 1.2*d_{1,core-1}$, such as $d_{2,core-2} \geq 1.3*d_{1,core-1}$, such as $d_{2,core-2} \geq *1.4\ d_{1,core-1}$, such as $d_{2,core-2} \geq 1.5*d_{1,core-1}$, such as $d_{2,core-2} \geq 1.8*d_{1,core-1}$, such as $d_{2,core-2} \geq 2.0*d_{1,core-1}$, such as $d_{2,core-2} \geq 2.5*d_{1,core-1}$, such as $d_{2,core-2} \geq 3.0*d_{1,core-1}$.

29. An optical fibre according to any one of the claims 25-28, wherein $2\pi/\lambda*d_{1,core-1}/2*NA_{core-1} \leq 3.5$, such as $2\pi/\lambda*d_{1,core-1}/2*NA_{core-1} \leq 3.0$, such as $2\pi/\lambda*d_{1,core-1}/2*NA_{core-1} \leq 2.5$.

30. An optical fibre according to any one of the claims 25-29, wherein $2\pi/\lambda*d_{1,core-1}/2*NA_{core-1} \leq 2.4$, such as $2\pi/\lambda*d_{1,core-1}/2*NA_{core-1} \leq 2.2$.

31. An optical fibre according to any one of the claims 25-30, wherein $2\pi/\lambda*d_{2,core-1}/2*NA_{core-1} \leq 1.8$, such as $2\pi/\lambda*d_{2,core-1}/2*NA_{core-1} \leq 1.6$, such as $2\pi/\lambda*d_{2,core-1}/2*NA_{core-1} \leq 1.4$, such as $2\pi/\lambda*d_{2,core-1}/2*NA_{core-1} \leq 1.2$, such as $2\pi/\lambda*d_{2,core-1}/2*NA_{core-1} \leq 1.0$, such as $2\pi/\lambda*d_{2,core-1}/2*NA_{core-1} \leq 0.8$.

32. An optical fibre according to any one of the claims 25-31, wherein $2\pi/\lambda*d_{2,core-2}/2*NA_{core-2} \leq 3.5$, such as $2\pi/\lambda*d_{2,core-2}/2*NA_{core-2} \leq 3.0$, such as $2\pi/\lambda*d_{2,core-2}/2*NA_{core-2} \leq 2.5$.

33. An optical fibre according to any one of the claims 25-32, wherein $2\pi/\lambda^*d_{2,core-2}/2^*NA_{core-2} \leq 2.4$, such as $2\pi/\lambda^*d_{2,core-2}/2^*NA_{core-2} \leq 2.2$.

34. An optical fibre according to any one of the preceding claims wherein said tapered optical fibre has a mode field that varies less than 20% in its radial extension along said longitudinal, optical axis from said first to said second cross section.

35. An optical fibre for guiding light at a predetermined wavelength, λ, and having a longitudinal, optical axis, comprising:
   a. a first core region disposed around said longitudinal, optical axis having a refractive index n_{core-1}, a numerical aperture NA_{core-1}, dimension $d_{1,core-1}$;
   b. a second core region surrounding said first core region, said second core region having a refractive index n_{core-2}, dimension $d_{1,core-2}$;
   c. an outer cladding surrounding said second core region, said outer cladding having a refractive index $n_{1,clad}$ or effective refractive index $n_{1,eff,clad}$;
   d. $n_{core-1} > n_{core-2}$;
   e. $2\pi/\lambda^*d_{1,core-1}/2^*NA_{core-1}$ in the range from 1.5 to 4;
   f. $2\pi/\lambda^*d_{1,core-2}/2^*NA_{core-2}$ in the range from 2.0 to 28.

36. A method of producing a tapered optical fibre, comprising:
   a. heating a section of the optical fibre of claim 35;
   b. stretching the optical fibre of claim 35 during heating; thereby providing first and second fibre cross sections being separated by a tapered length of the optical fibre over which the cross-sectional physical dimensions of the fibre are tapered down from the first to the second cross section; and
   c. optionally cleaving the optical fibre after stretching at one or more positions.

37. The method of claim 36, wherein the tapered optical fibre is stretched and optionally cleaved to provide a second cross section in which the inner core has a dimension $d_{2,core-1}$, and wherein $2\pi/\lambda * d_{2,core-1}/2 * NA_{core-1}$ is less than 2.

38. The method of claim 36 or 37, wherein the tapered optical fibre is stretched and optionally cleaved to provide:

   a. said first core region having a dimension $d_{2,core-1}$ in said second cross section;
   b. said second core region having a numerical aperture NA_{core-1} and dimension $d_{2,outer}$ in said second cross section;
   c. said outer cladding surrounding said second core region and having a refractive index $n_{2,clad}$ or effective refractive index $n_{2,eff,clad}$ in said second cross section; and
   d. wherein
   e. $d_{1,core-1} > 1.3\ d_{2,core-1}$;
   f. $d_{2,core-2}$ is larger than or equal to $d_{1,core-1}$;
   g. $2\pi/\lambda * d_{2,core-1}/2 * NA_{core-1}$ is less than 2;
   h. $2\pi/\lambda * d_{2,core-2}/2 * NA_{core-2}$ in the range from 1.5 to 4.

39. The method according to any one of claims 36-38 wherein the stretching is performed using a fibre tapering rig after production of the optical fibre of claim 26.

40. The method according to any one of claims 36-38 wherein the stretching is performed during production of a fused, tapered fibre bundle comprising the optical fibre of claim 26.

41. A method of producing a tapered optical fibre comprising the steps of:

   a. providing a preform comprising cross-sectional characteristics of the fibre of claim 35 on a larger scale;
   b. placing said preform in an optical fibre drawing tower setup;
   c. pulling optical fiber from a heated end of said preform;
   d. varying fibre pulling speed and/or preform feed speed during fibre pulling.

42. A method for combining a first optical device having a light guiding structure with a mode field with diameter MFD_f and a second optical device having a light guiding structure with a mode field with diameter MFD_s different from MFD_f, comprising:
    a. providing an optical fibre according to any one of claims 1-34 or a tapered optical fibre realized using the method of any one of the claims 36-41 having a thick end with MFD_1 substantially similar to MFD_f and a reduced-diameter end with MFD_2 substantially similar to MFD_s;
    b. attaching said thick end to said first optical device;
    c. attaching said reduced-diameter end to said second optical device.

43. An article comprising a photonic crystal fibre according to any one of claims 1-34.

44. An article according to claim 43 wherein the article is a coupler.

45. An article according to claim 43 wherein the article is a fibre amplifier or fibre laser.

46. A photonic crystal fibre comprising
    a. a multi-mode core region for propagating light in a longitudinal direction of said photonic crystal fibre,
    b. an air-clad region comprising a multitude of longitudinally extending spaced apart micro-structural elements surrounding said multi-mode core region,
    c. the photonic crystal fibre comprising a first and a second end, wherein cross-sectional dimensions of said multimode core region and said air-clad region are reduced from said first end to said second end so that brightness is essentially conserved.

47. A photonic crystal fibre according to claim 46 wherein said cross sectional dimensions of the multimode core region and the air-clad region are smaller at said second end than at said first and whereby it is achieved that the PCF has a larger numerical aperture at said second end than at said first end.

48. A photonic crystal fibre according to claim 46 or 47 wherein the numerical aperture NA and maximum cross sectional dimension D of the multimode core region at said first and second ends NA_1, D_1 and NA_2, D_2, respectively, are adapted so that ratio NA_1*D_1/NA_2*D_2 is in the range from 0.5 to 1.5 such as from 0.8 to 1.2, such as from 0.9 to 1.1.

49. A photonic crystal fibre according to any one of claims 46-48 wherein said air-clad comprises at least one ring of longitudinally extending micro-structural elements.

50. A photonic crystal fibre according to claim 49 wherein the minimum boundary to boundary distance b between neighbouring micro-structural elements of the air-clad in an annular direction is substantially constant for all elements of a particular ring.

51. A photonic crystal fibre according to claim 49 or 50 wherein the ratio D/b of the maximum cross sectional dimension of the multimode core region D to the minimum boundary to boundary distance b between neighbouring elements of a ring of elements of said air-clad, is substantially equal at the cross sections of said first and second ends of the PCF.

52. A photonic crystal fibre according to claim 51 wherein the ratio $(D_1/b_1)/(D_2/b_2)$ of the ratio D/b at said first and second ends, is in the range from 0.5 to 1.5 such as from 0.7 to 1.2, such as from 0.8 to 1.0, such as from 0.8 to 0.9.

53. A photonic crystal fibre according to any one of claims 46-52 wherein said multimode core region is homogeneous and made of a single material with refractive index $n_{MM\ core}$.

54. A photonic crystal fibre according to any one of claims 46-53 wherein said multimode core region comprises a single mode or few-mode core region.

55. A photonic crystal fibre according to claim 54 wherein said single mode or few-mode core region is homogeneous and made of a single material with refractive index $n_{SM\ core}$ and/or said single mode or few-mode core region comprises optically active material, such as one or more rare-earths.

56. A photonic crystal fibre according to any one of claims 46-55 wherein at least some of said micro-structural elements are holes or voids.

57. A photonic crystal fibre according to any one of claims 46-56 wherein said multimode core region comprises a core region surrounded by an array of air holes or voids.

58. A photonic crystal fibre according to any one of claims 46-57 wherein said PCF comprises refractive index modifying, photosensitive and/or optically active dopant material(s).

59. A photonic crystal fibre according to any one of claims 46-58 wherein said PCF comprises one or more optically reflecting elements such as one or more Bragg gratings.

60. A photonic crystal fibre according to any one of claims 46-59 wherein said PCF comprises a rare-earth doped region, comprising rare earth dopant ions selected from the group comprising Er, Yb, Nd, Ho, Sm or Tm and combinations thereof.

61. A photonic crystal fibre according to any one of claims 46-60 wherein the photonic crystal fibre is adapted to guide light comprising a wavelength in the ultra-violet to infrared regime.

62. A photonic crystal fibre according to any of the claims 46-61 wherein the photonic crystal fibre further comprises a solid cladding region surrounding said multimode core region, said solid cladding region having a refractive index, $n_{clad\text{-}solid}$ smaller than $n_{MM\ core}$.

63. A photonic crystal fibre according to any of the claims 46-61 wherein the said air-clad region comprises a background material of refractive index, $n_{clad\text{-}solid}$, wherein $n_{clad\text{-}solid}$ is smaller than $n_{MM\ core}$.

64. A photonic crystal fibre according to claim 62 or 63 wherein $\mathrm{sqrt}(n^2_{MMcore}\ n^2_{clad\text{-}solid})$ is larger than 0.12, such as larger than 0.15, such as larger than 0.22.

65. A photonic crystal fibre according to claim 64 wherein said air-clad region in a portion of said first end is collapsed.

66. A photonic crystal fibre according to any one of claims 54-65 wherein the singlemode or few mode core region has a predetermined refractive index profile $n_{core\text{-}1}$ and the photonic crystal fibre further comprises a second core region surrounding the singlemode or few mode core region and having a predetermined refractive index profile $n_{core\text{-}2}$.

67. A photonic crystal fibre according to claim 66 wherein the photonic crystal fibre further comprises a cladding region surrounding the second core region, the cladding region comprising a multitude of longitudinally extending spaced apart micro-structural holes disposed in a cladding material, the cladding material having a refractive index n_{clad}, the holes having cross sectional dimensions $d_i(z)$ and mutual centre to centre distances $\Lambda_{ij}(z)$, z being a coordinate along the longitudinal axis of the optical fibre;
the singlemode or few mode core region, the second core region and the cladding region being located within the multi-mode core region, wherein the cross-sectional dimensions, the refractive index profiles $n_{core\text{-}1}$ and $n_{core\text{-}2}$ of the core regions, the refractive index n_{clad} of the cladding region and the cross sectional dimensions and mutual centre

to centre distances of the micro-structural holes at the first and second ends of the optical fibre are adapted to provide a mode field of a guided mode of the optical fibre with a diameter MFD_1 at the first end, and a mode field with a diameter MFD_2 at the second end, and wherein MFD_2 is larger than or equal to MFD_1.

68. A photonic crystal fibre according to claim 67 wherein the micro-structural holes are arranged in a substantially periodic pattern when viewed in a cross section of the optical fibre perpendicular to the longitudinal axis, the periodicity being defined by the location of the centres of the micro-structural elements.

69. A photonic crystal fibre according to claim 67 or 68 wherein in the second fibre cross section, the cross sectional dimensions of at least the innermost holes are larger than zero.

70. A photonic crystal fibre according to claim 69 wherein at least the innermost holes have substantially similar ratio of cross sectional dimension to mutual centre to centre distance d/Λ at the first and second cross sections.

71. A photonic crystal fibre according to claim 66 wherein the photonic crystal fibre further comprises cladding region surrounding the second core region, the cladding region having a refractive index n_{clad}, the singlemode or few mode core region, the second core region and the cladding region being located within the multi-mode core region, wherein the refractive index profiles of the singlemode or few mode and second core regions and the refractive index n_{clad} of the cladding region are adapted to provide a mode field of a guided mode of the optical fibre with a diameter MFD_1 at the first end, and a mode field with a diameter MFD_2 at the second end, and wherein MFD_2 is larger than or equal to MFD_1.

72. A photonic crystal optical fibre according to any one of claims 66-71 further comprising an intermediate region surrounding the singlemode

or few mode core region and being surrounded by the second core region.

73. A photonic crystal fibre according to claim 72 wherein the intermediate region is disposed adjacent to the singlemode or few mode and second core regions.

74. A photonic crystal fibre according to claim 72 or 73 wherein the intermediate region exhibits a predetermined refractive index profile n_{ir} and wherein $n_{ir} < n_{core-1}$ and $n_{ir} < n_{core-2}$.

75. A photonic crystal fibre according to any one of claims 73-75 wherein the geometrically averaged refractive index $n_{g,core-1,ir}$ of the singlemode or few mode core and intermediate regions is substantially equal to the refractive index n_{core-2} of the second core region.

76. A photonic crystal fibre according to claim 75 wherein the absolute value of the difference between $n_{g,core-1,ir}$ and n_{core-2} is smaller than $5 \cdot 10^{-3}$, such as smaller than $1 \cdot 10^{-3}$, such as smaller than $0.8 \cdot 10^{-3}$, such as smaller than $0.5 \cdot 10^{-3}$, such as smaller than $0.3 \cdot 10^{-3}$, such as smaller than $0.1 \cdot 10^{-3}$.

77. A photonic crystal fibre according to any one of claims 66-76 wherein the refractive index profile of the singlemode or few mode core region is a step-index-profile with an index-step Δn_1 down to the refractive index n_{core-2} of the second core region.

78. A photonic crystal fibre according to claim 77 wherein Δn_1 is larger than $1 \cdot 10^{-3}$, such as larger than $5 \cdot 10^{-3}$, such as larger than $6 \cdot 10^{-3}$, such as larger than $10 \cdot 10^{-3}$.

79. A photonic crystal fibre according to any one of claims 66-78 wherein the refractive index profile of the singlemode or few mode core region is a step-index-profile with an index-step Δn_{1-clad} down to the refractive index of the cladding material n_{clad}.

80. A photonic crystal fibre according to claim 79 wherein $\Delta n_{1\text{-clad}}$ is larger than $1 \cdot 10^{-3}$, such as larger than $5 \cdot 10^{-3}$, such as larger than $6 \cdot 10^{-3}$, such as larger than $10 \cdot 10^{-3}$.

81. A photonic crystal fibre according to claim 13 when referring to any one of claims 66-70 or 72-80 wherein Δn_1 is identical to $\Delta n_{1\text{-clad}}$.

82. A photonic crystal fibre according to any one of claims 72-81 wherein the refractive index profile of the intermediate region is a step-index-profile with an index-step Δn_2 up to the refractive index $n_{core\text{-}2}$ of the second core region.

83. A photonic crystal fibre according to claim 82 wherein Δn_2 is larger than $0.1 \cdot 10^{-3}$, such as larger than $0.5 \cdot 10^{-3}$, such as larger than $1 \cdot 10^{-3}$, such as larger than $5 \cdot 10^{-3}$, such as larger than $10 \cdot 10^{-3}$.

84. A photonic crystal fibre according to any one of claims 72-83 wherein the refractive index profile of the intermediate region is a step-index-profile with an index-step $\Delta n_{2\text{-clad}}$ up to the refractive index of the cladding material n_{clad}.

85. A photonic crystal fibre according to claim 84 wherein $\Delta n_{2\text{-clad}}$ is larger than $0.1 \cdot 10^{-3}$, such as larger than $0.5 \cdot 10^{-3}$, such as larger than $1 \cdot 10^{-3}$, such as larger than $5 \cdot 10^{-3}$, such as larger than $10 \cdot 10^{-3}$.

86. A method of manufacturing a photonic crystal fibre, the method comprising the steps of:
   a. providing a preform comprising longitudinally extending elements comprising tubes or rods with specific cross sectional dimensions, the preform having a fixed end and a drawing end
   b. optionally sealing at least one end of said preform
   c. drawing said preform from said drawing end with a predetermined drawing speed in one or more steps including varying said predetermined drawing speed to provide a PCF,

having a first end and a second end wherein said first end has cross sectional dimensions that are larger than corresponding cross sectional dimensions of said second end.

d. optionally applying a controlled pressure to said fixed end of said preform and optionally varying said applied pressure to control cross sectional dimensions of said drawn PCF.

87. An article comprising a photonic crystal fibre according to any one of claims 46-85.

88. Use of a photonic crystal fibre according to any one of claims 46-85.

89. An optical coupler for coupling light form a plurality of input fibres into one fiber, said optical coupler comprising

a. • a first region with at least two input fibers;

b. • a second region wherein said input fibres are tapered and are fused together;

wherein said input fibers in at least a part of the length of said second region of the coupler are surrounded by an arrangement of holes.

90. An optical coupler according to claim 89, wherein said coupler further comprises a third section where the input fibers are completely fused to each other, said third section comprises a single output end, said output end preferably comprising an air-clad in said single output end.

91. An optical coupler according to claim 89 or 90, wherein said input fibres are solid fibres.

92. An optical coupler according to any one of the claims 89-91, wherein a majority of said input fibres are multi-mode fibres.

93. An optical coupler according to claim 92, wherein all of said input fibres are multi-mode fibres.

94. An optical coupler according to claim 92, wherein one of said input fibres is a single-mode fibre.

95. An optical coupler according to any of the claims 90 to 94, wherein said output end has an NA larger than 0.45, such as larger than 0.50, such as larger than 0.55, such as larger than 0.60.

96. An optical coupler according to any one of claims 89-95 comprising at least one input fibre constituted by an optical fibre according to any one of claims 1-34 or a photonic crystal fibre according to any one of claims 46-85.

97. An optical coupler according to claim 96 wherein an input fibre constituted by an optical fibre according to any one of claims 1-34 or a photonic crystal fibre according to any one of claims 46-85 is centrally located in the optical coupler.

98. An optical system comprising an optical coupler according to any of the claims 89 to 97 and an air-clad optical fibre, said air-clad optical fibre having substantially similar NA and air-clad dimension as the optical coupler.

99. A method for fabricating an optical coupler, said method including the steps of

a. • providing a plurality of input fibres

b. • proving a hollow ring element comprising a ring of holes, preferably substantially parallel to the center axis of the ring element, said ring element has a central opening

c. • optionally sealing off holes in said ring element in at least one section of said ring element

d. • inserting said plurality of input fibres into said central opening such that a part of their length is within said opening and another part of their length is outside said opening

e. • heating said ring element at a position or in a section where said input fibres are present in said opening

f. • tapering said ring element in a section where said input fibres are present in said opening

g. • optionally performing said heating and tapering in the same step

h. • optionally apply a less-than-atmospheric pressure in said opening during said heating and/or tapering

i. • optionally cleave said ring element, preferably at a section of smallest dimension after tapering